Robot without Organs? Assemblage, Agency and Networked Sociality in Human-Robot Interaction

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Abstract

In this paper, we give an overview of the results of a Human-Robot Interaction experiment, in a near zero-context environment. We stimulate the formation of a network joining together human agents and non-human agents in order to examine emergent conditions and social actions. Human subjects, in teams of 3-4 are presented with a task: to coax a robot (by any means) from one side of a table to the other, not knowing with what sensory and motor abilities the robotic structure is equipped. On the one hand, the "goal" of the exercise is to "move" the robot through any linguistic or paralinguistic means. But, from the perspective of the investigators, the goal is both broader and more nebulous: to stimulate any emergent interactions whatsoever between agents, human or non-human. Here we discuss emergent social phenomena in this assemblage of human and machine, in particular turn-taking and discourse, suggesting (counter-intuitively) that the "transparency" of non-human agents may not be the most effective way to generate multi-agent sociality.

Introduction

One strand of research in Artificial Intelligence (AI) in general and multiagent systems (MAS) research in particular has been concerned with the simulation of extant life–genetic algorithms, neural nets, ethological simulations like swarming, etc. Another strand (less popular since its zenith in the early 1990s) explores the possibility that artificial agents might themselves constitute a kind of life (Helmreich 1998; Langdon 1995). There have been countless insights over the past three decades in AI and cognitive science in general that have hinged upon isomorphisms between these two "phyla": the biological, on the one hand, and the machinic, on the other, with great insights into, say, mirror neurons (on the biological side) and genetic algorithms (on the machine) side, generated by cross-experiments. All of these, however, ignore the extant to which humans and non-humans together are imbricated in a kind of "second-nature" where nature, machine and human are connected together in complex, mutually constitutive ways, precisely what Deleuze and Guattari (1980) invoke in their conception of "machinic assemblage," the temporary coming-together of heterogeneous elements linked not by filiation but by transformation, an "unnatural participation" that links the human and the non-human.

In other words, defining "humans" and "machines" so as to emulate one with the other may be ontologically problematic when the two are multiply interpenetrated in the first place. In Human-Computer Interaction (HCI) and Human-Robot Interaction (HRI), researchers attempt to accommodate machines to human needs, creating, for example, "socially acceptable" robots for future, human interaction (Koay et *al*. 2006). But these kinds of interventions are premised on an unchanging human to which non-human agents might be compared.

Our research looks at our cyborg present–a world where acting "human" always already involves machinic practice (Collins 2007; Trajkovski 2007). For us, the question in HCI is not to better accommodate non-human agents to humans by more effective "interfaces" better emulating human behavior but to maximize our existing cyborg lives–the bodily hexis, communications, socialities and cultural schema that proliferate in the interstices of the human and the machine.

In the following paper, we report on a series of ongoing experiments involving human agent-non-human agent interaction. In these, we consider the human-robot as our proper object, and the actions of all involved agents as formative of a temporary, shifting, cognitive, social and cultural network. These interactions, we argue, can be considered properly social and, in the Durkheimian sense, emergent, that is, not explicable at the level of the individual agent (Sawyer 1991). In this, we draw upon synergistic insights from a variety of academic disciplines–AI, cybernetics, cognitive science, science studies, cultural studies and anthropology, each examining the cyborg from a slightly different perspective. All of them, though, might be said to engage cybernetics, and in particular the "second generation" cybernetics of Humberto Maturana and Francisco Varela (1980). Looking to "autopoeitic" systems (literally, systems that make themselves), Maturana and Varela undermined dichotomies of subject and object by focusing on the way that organisms "structurally couple" to their environments, that is, not so much adapting to them as producing them in the course of recursively producing themselves. It is the system itself that is generative of change, rather than some objective reality outside of it. By the 1990s, Varela (1999:48) had extended these insights into autopoeitic systems to more open systems, including human perception itself, describing, for example, vision as "emergent properties of concurrent subnetworks, which have a degree of independence and even anatomical separability, but cross-correlate and work together so that a visual percept is this coherency."

Applying this to HCI means, ultimately, questioning the extent to which action should be most usefully considered first and foremost a product of human intention and, instead, leading us to a model of cognition and social life that arises out of the interaction of a heterogeneity of agents. This is what Michael Woolridge (2002:105) means when he reminds us that "There's no such thing as a single agent system." The strength of cybernetics and multiagent systems research is precisely this radical deconstruction of the Leibnizian monad for models of life that focus less on the "molar" than on the traffic between agencies.

This, we believe, has its philosophic appeal, but this is not our primary reason for enjoining this research; moving to this dynamic, networked model of HCI promises to move us beyond unproductive abstractions ("the human") to real, empirical understandings of humans living in and through their machine worlds (as well as machines "machining" through their human worlds). That is, ultimately (and contrary to the etymology), these approaches gesture towards a more anthropological (and sociological) approach to the study of cyborg lives, implicit in Gregory Bateson's (1972:318) parable:

> "Consider a man felling a tree with an axe. Each stroke of the axe is modified or corrected, according to the shape of the cut face of the tree left by the previous stroke. This self-corrective (i.e., mental) process is brought about by a total system, trees-eyes-brain-muscles-axe-stroke-tree; and it is this total system that has the characteristics of immanent mind."

The material world around us is, through processes of externalization and sublation, alternately appears as part of an objective outside, or a subjective inside, but the lines between the two are continuously negotiated in the course of daily life. It is a short step from this central insight to a full-blown "cyborg anthropology" that, as Downey, Dumit and Williams (2000:344) explain, holds "that machines and other technologies are attributed agency in the construction of subjectivities and bounded realms of knowledge."

But it would be equally misleading to represent these emergent cyborgs as bounded entities, i.e., simply expanding reified notions of the subject to include that subject's machines. This is the mistake that Dobashi (2005:233) makes in a study of Japanese housewives and keitai (cellular phones). Rejecting a determinist framework where "housewives" and "cell phones" are considered as discrete entities, Dobashi looks instead "to the simultaneous development of both processes into one undividable entity." But this "cyborgification of housewives" (233) is equally flawed, simply substituting "human + machine" for "human," augmenting the human with the non-human, the non-human with the human. The more productive direction would be to see these networks unfolding in time, bringing together multiple agents in temporary communication; that is, we may be embedded in machinic networks, but to hypostatize their dynamic heterogeneity would be to replace one metaphysics with another.

What we mean (or should mean) by "cyborgification" is something much more shifting and protean–part of the exciting promise of the cyborg is, after all, the possibility of novel ways of thinking and acting. To this we look to the "actor-network theory" (ANT) that examines just such sites of "hybridity," i.e., those complex translations between humans and nonhumans that momentarily coalesce into novel forms before dispersing into other systems. This is Latour's "network", not to be confused with the more static configurations of routers and servers. As Jan Harris (2005:169) summarizes,

> "Thus rather than a polarity of a subject and object in which the former, via the methodology of natural science, attains knowledge of the latter, we have a network of 'circulating' references or translations. The objects of the field imply the facts of the laboratory, likewise these facts return us to the field. What is important, then, is neither brute objects nor the incorporeal facts that express them, but the processes that lead us from one to the other. These processes are a variety of facts of organization, in this manner the order of things revealed by science emerges as the result of an ordering of things. "

THE EXPERIMENT

In the following experiment, we stimulate the formation of a network joining together human agents and non-human agents in order to examine emergent conditions and social actions. 4-5 volunteers drawn from undergraduate anthropology and cultural studies classes, after giving informed consent, were presented with a task: to coax a robot (by any means) from one side of a table to the other.

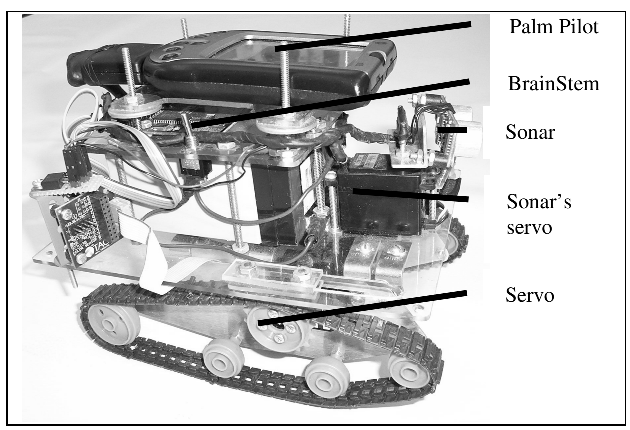

Figure 1. Carol, the robot used in the experiments, and its relevant components.

Carol, a robot built in the Cognitive Agency and Robotics Laboratory (CARoL) was used in these experiments. The basic microcontroller that we use to control our robots in CARoL is Acroname's BrainStem®. The BrainStem is a microcontroller that is supported by various operating systems. Each module can operate as a slave device, run concurrent C-like programs (in a programming language called TEA) and handle reflexive actions automatically. The usefulness of this module is linked to its capability for controlling multiple analog and digital sensors. In addition, the BrainStem can operate up to four servos, which allows it to be used in a multitude of operations.

Table 1. The menu implemented in the program of the robot for the second iteration.

Position of first obstacle (sonar facing forward)	Side the sonar moves to	Second obstacle	Robot moves
Close (≤6 inches)	Left	Close	Forward
		Far	Forward
		Too Far	Reset
Far (6-12 inches)	Right	Close	Left
		Far	Right
		Too Far	Reset
Too far > 12 inches	Reset menu		

Table 2. Statistics on talking in the first iteration.

		Frequency	%	Valid %	Cumulative %
Valid	talk team social	2	1.9	6.5	6.5
	talk robot order	28	27.2	90.3	96.8
	talk robot social	1	1.0	3.2	100.0
	Total	31	30.1	100.0	
Missing	System	72	69.9		
Total		103	100.0		

Table 3. Statistics on movements in the first iteration.

		Freq	%	Valid %	Cumulative %t
Valid	hand front	20	19.4	27.8	27.8
	hand side	10	9.7	13.9	41.7
	hand back	4	3.9	5.6	47.2
	gesturing	4	3.9	5.6	52.8
	moving position	2	1.9	2.8	55.6
	rotate left	5	4.9	6.9	62.5
	rotate right	6	5.8	8.3	70.8
	move forward	6	5.8	8.3	79.2
	move back	13	12.6	18.1	97.2
	rotate confused/twitch	2	1.9	2.8	100.0
	Total	72	69.9	100.0	
Missing	System	31	30.1		
Total		103	100.0		

The BrainStem can be controlled through two programs: the Console and GP. These programs have the ability to control movement and sensor readings, help in debugging, uploading files, and executing reflexes. This platform works well with PalmOS-based PDAs, which we use for expanding the computational and storage power of the basic BrainStem unit. The robot used for these experiments is shown in Figure 1. The experiment uses its two servos for movement of the tracks (left and right track), and another one to move the sonar sensor that is mounted for obstacle detection. The control is hosted on the Palm Pilot on top of the robotic structure.

For the first iteration, Carol was programmed to execute a simple obstacle avoidance program. When the sonar detects an obstacle within its range, it backs up, and scans for obstacles 90 degrees to the left and 90 degrees to the right with its sonar. Afterwards, it either turns full left of full right, depending on which side the farthest obstacle is detected at the time of the sonar scan. In order for the robot to start moving, it needs to detect an obstacle very close to its sonar (a hand movement in front of it would start the program). Initially, the robot is placed on the table in such a way that its axis of movement is at a 45 degree angle with the edges of the table that it is placed on.

For the second iteration of the experiment, we emulated a 2-level menu to control the movements of the robot. The menu details are given in Table 1. When the sonar registers an obstacle within 12 inches from it, it evaluates whether it is in the 0-6 or 6-12 inch region, and turns left of right. Depending on whether the next obstacle is close or far, it executes a command. When the obstacle is further than 12 inches, after 10 seconds, the menu resets.

Volunteers were given no information on the robot's programming or sensors. And yet, this is not exactly a "0-context" experiment. On the one hand, the "goal" of the exercise is to "move" the robot through any linguistic or paralinguistic means.

Table 4. Talking during second iteration.

		Freq.	%	Valid %	Cumulative %
Valid	talk team start.	30	13.0	36.1	36.1
	talk team social	18	7.8	21.7	57.8
	talk robot order	21	9.1	25.3	83.1
	talk robot social	14	6.1	16.9	100.0
	Total	83	35.9	100.0	
Missing	System	148	64.1		
Total		231	100.0		

Table 5. Relevant movements during second iteration.

		Freq.	%	Valid %	Cumulative %
Valid	hand front	42	18.2	28.4	28.4
	hand side	40	17.3	27.0	55.4
	hand back	4	1.7	2.7	58.1
	tapping/snapping	10	4.3	6.8	64.9
	gesturing	1	.4	.7	65.5
	moving position	2	.9	1.4	66.9
	rotate left	27	11.7	18.2	85.1
	move forward	14	6.1	9.5	94.6
	rotate confused/twitch	8	3.5	5.4	100.0
	Total	148	64.1	100.0	
Missing	System	83	35.9		
Total		231	100.0		

But, from the perspective of the investigators, the goal is both broader and more nebulous: to stimulate any emergent interactions whatsoever between agents, human or non-human.

Of course, this begs the question of the observer, a problem that Hayles (1999) has identified as the most pressing legacy of first-generation cybernetics. Are things "objectively" interesting or emergent, or are they only this way from a given perspective? For Francisco Varela et al (1991:172), this needs not lead to solipsism; cognitive categories like colors exist neither wholly "outside" nor "inside" the perceiving agent. For Latour, the observer and the observed form part of "network" enabling the production of facts. As Jan Harris (2005:169) summarizes,

> "Thus rather than a polarity of a subject and object in which the former, via the methodology of natural science, attains knowledge of the latter, we have a network of 'circulating' references or translations. The

objects of the field imply the facts of the laboratory, likewise these facts return us to the field. What is important, then, is neither brute objects nor the incorporeal facts that express them, but the processes that lead us from one to the other. These processes are a variety of facts of organization, in this manner the order of things revealed by science emerges as the result of an ordering of things. “

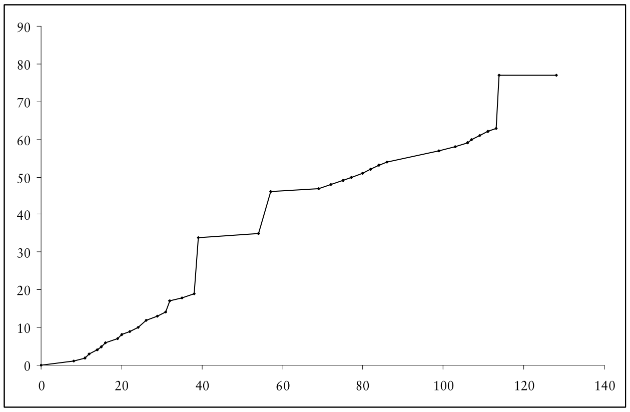

Figure 2. Path covered by the robot in movement in generic distance units, first iteration.

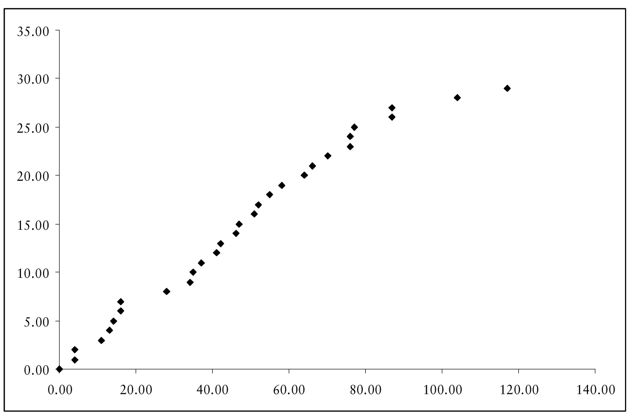

Figure 3. Talking instances, over time, for the first iteration of the experiment.

This insight has methodological significance for our experiment. Rather than take a more computational perspective on multi-agent interaction (using, for example, the robot’s programming as the basis for understanding agents’ interaction), we have adopted the androcentric perspective of the human observers, examining emergent behaviors through a video camera (itself a part of the actor-network).

Here we present data and analyze two examples of human-robot interaction from our research.

RESULTS

By transcribing speech and actions and coding them, we generate a map of agents’ actions as they unfold over time, understood as linguistic actions (after Austin) or paralinguistic actions (movements, gesture); data were also analyzed according to frequency and cross-tabulated. For the first iteration, the summary of the talk and movement are given in Tables 2 and 3 respectively, whereas Tables 4 and 5 summarize the second iteration. Some of the parameters of the interactions sessions derived from the transcripts are shown in Figures 2-5.

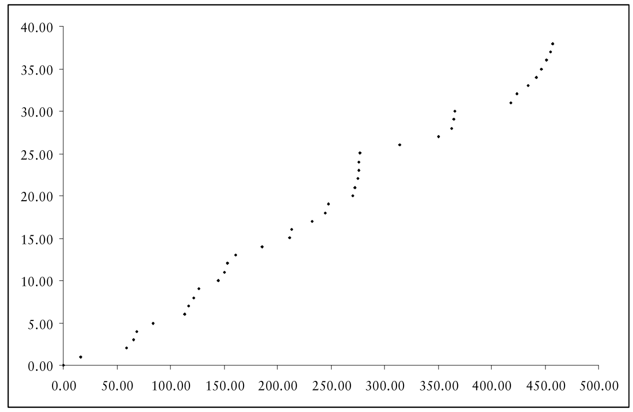

Figure 4. Cumulative dynamics (in number of occurrences) of hand movements for all team members over time (in seconds) during the second experiment.

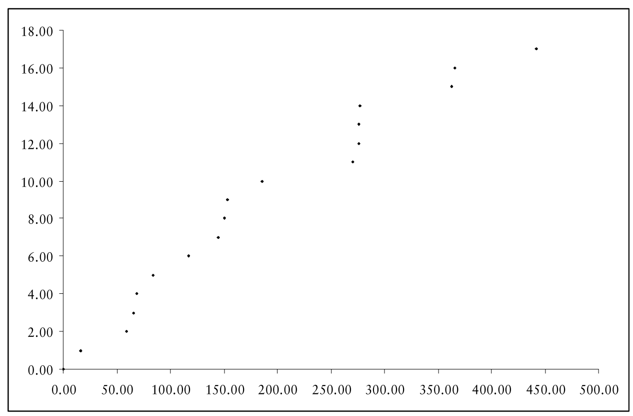

Figure 5. Cumulative dynamics (in number of occurrences) of hand movements for team member A over time (in seconds) during the second experiment.

But we also find here examples of emergent socialities. That is, the artifice of the experiment–guiding and coaxing a robot into a goal, both specifies a certain kind of stereotypical structure (a team of human agents working towards a goal) while introducing a potential element of disorder, a non-human agent with which the human agents must interact. The first may not be generative of any particular novelty (as the results of group work in the classroom oftentimes suggests). But the second configuration lays the ground-work for novelty by introducing the confusion of a more complex, 2-level menu. This has the effect of generating more interaction between agents, rather than less, a counter-intuitive finding that we explore more below. In what Michel Serres calls the “parasite,” perfectly transparent information–i.e., the perfect identity of speaker and hearer–renders conversation unnecessary. Communication only takes place in the presence of disorder (miscommunication, misapprehension, etc.). As Brown (2002:16-17) writes,

> "In information terms, the parasite provokes a new form of complexity, it engineers a kind of difference by intercepting relations. All three meanings then coincide to form a 'parasite logic'–*analyze* (take but do not give), *paralyze* (interrupt usual functioning), *catalyze* (force the host to act differently). This parasite, through its interruption, is a catalyst for complexity. It does this by impelling the parties it parasitizes to act in at least two ways. Either they incorporate the parasite into their midst–and thereby accept the new form of communication the parasite inaugurates–or they act together to expel the parasite and transform their own social practices in the course of doing so."

In the following examples, the robot acts the part of the "parasite," interrupting the flat functioning of a team of human agents and forcing it to act differently.

```
 b c
|--------------------------r-----------| a
 d
```

0:52	d	Go straight
0:52	c	Go straight
0:52	r	[Move back]
0:55	d	[left hand in front]
0:55	r	[rotate left]
0:56	d	[left hand in front]
0:56	r	[move back]
0:58	a	[right hand side, then right hand front]
0:58	r	[rotate right]
1:00	c	[right hand in front]
1:00	r	[move forward off table]
1:01	a	[catch falling robot with left hand–reset]
1:02	r	[twitch]
1:04	a	Forward. Go straight.
1:05	c	[let hand in front]
1:05	r	[move back]
1:07	c	[left hand on right side]
1:07	r	[rotate left]
1:08	r	[move forward]
1:09	c	[right hand in front]
1:10	b	Left.
1:11	c	Left!
1:11	c	[point to the left]
1:11	r	[move back]
1:13	b	Left. To the left.
1:14	r	[rotate left]
1:15	r	[move forward]
1:17	b	There we go.

Transcript 1. See text for comments. Roman letters a-d correspond to the human agent's; 'r' to the non-human agent. Text in brackets refers to gesture and movement. The schematics at the top of the transcript show the relative position of the human and the nonhuman subjects on and around the table.

In the first example, we see examples of emergent sociality through turn-taking. The human agents attempt to form what are known as "adjacency pairs" with the non-human agent, initiating a conversational turn (by speech or gesture) that the non-human agent is supposed to complete by moving in the direction of the goal. This is isomorphic to one of the basic "rules" of turn-taking in conversation:

> "If the turn-so-far is so constructed as to involve the use of a 'current speaker selects next' technique, then the party so selected has the right and is obliged to take next turn to speak; no other have such rights or obligations, and transfer occurs at that place." (Sacks et al 704).

```
dab
|-----r---------------------------------------|
 ecf
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06.44	a	If it wants to kill itself, who are we to tell it no?
06:47	d	Well, I'm here to catch it if it tries to go.
06:48	a	Turn it that way. Turn it.
06:49	d	Hey can we turn it that way? It's getting ready to fall off, dude.
06:50	r	[rotates right, left]
07:00	r	[pi repositions robot]
07:02	c	[Right hand close front; left hand close side]
07:05	c	[right hand close front; left hand close side]
07:05	b	[right hand close front]
07:05	e	Right hand above front
07:06	r	[moves forward, stops]
07:08	b	Female hands?
07:09	b	Right hand front
07:16	r	[rotates left]
07:20	a	It doesn't like you. You're not cussing at it. It does not fear you.
07:21	b	[right hand close front]
07:21	e	[left hand close front, right hand front above]
07:21	c	[left hand side]
07:21	b	We need another hand on that side
07:24	r	[rotates right]
07:24	e	It's moving at least
07:30	r	[Moves forward]
07:31	d	[right hand front]
07:32	d	Not towards me, towards the goal there, come on.
07:35	d	[right hand close front, left hand close side]
07:25	r	[rotate left]
07:42	a	We're cussing it!
07:42	a	You're in the trash if you don't get moving, buddy.
07:46	d	Go that way, the way you were looking before.
07:48	b	Maybe if you guys come over here and . . .

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fcab
d|r-----------------------------------------|
e
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Transcript 2. Excerpt from the second experiment transcript. See text for the comments on this transcript.

If the nonhuman agent 'r' completes the adjacency pair, then the human agent is entitled to another turn. This is an in-built "bias" in turn-taking, which privileges the "current speaker selects next" turn allocation to the subordinate rule, self-selection (see transcript 1).

And this solves a typical problem–the problem of conversational bias. Sacks et al (1974:712) write:

> "The 'last as next' bias, however, remains invariant over increases. Not only does this have the effect of

stimulating "self-selects" turns in the human agents and, in the comparison to the first examples, increasing the total number of parties – and, with each additional increment in the number of parties, tends progressively to concentrate the distribution of turns among a sub-set of the potential next speakers."

This is confirmed in such stereotypical settings as classroom discourse, where, unless the instructor intervenes, conversation quickly concentrates around a handful of speakers, leaving the rest of the class out of the conversation. Here, the introduction of a non-human agent has the effect of "selecting" another speaker by simply moving down the table–the initial human-agent is not able to take advantage of their prior right to initiate another adjacency pair after the non-human agent has moved out of range. A begins his turn, but quickly remits to B when the robot moves down the table out of range. The non-human agent allows for the 'last as next' bias to be superseded by 'self-select' and, therefore, an engagement with all of the human agents in the robot's trajectory.

The above example shows how the non-human agent intervenes in what might be thought of as an example of ordinary turn-taking, facilitated by the robot's simple obstacle avoidance. Once human agents understand the non-human agent's drive, then forming stereotypical adjacency pairs with it is unproblematic. However, the second case demonstrates what might be thought of as a "conversational anomaly" where the non-human agent fails to complete adjacency pairs altogether.

Here, the non-human agent is unresponsive or, alternately, responds in an undesirable way to the speech and gestures of the human agents. If the nonhuman agent ("r") does not respond, however, then this constitutes a conversation "lapse" and allows another human agent to self-select, initiating her own adjacency pair with the non-human agent. In the case of primary conversation, it means that the current speaker (the human agent) has failed to "select" the next speaker (the non-human agent). As Sacks et al (1974:715) write, "At any transition-place where none of the options to speak has been employed, the possibility of a lapse, and thus discontinuous talk, arises."

Not only does this have the effect of stimulating "self-selects" turns of linguistic and paralinguistic actions in the human agents, but it results in at least two novel behaviors: 1) a level of strategy and metacommentary directed not at the robot, as in the first example, but to the other human agents and 2) the invention of "co-operative" turns, i.e., instances (like the in the interval between 7:02-7:05 in Transcript 2, where three human agents train their hands on the nonhuman agent at the same time). This particular example, with human agent "b" suggesting that the robot is moving because of "female hands" is significant in that adjacency pairs up to that point had been dominated by 2 of the male agents, a and d, respectively. As Gibson (2005:135) reminds us,

> "The second thing we know about conversation is that not everyone is dealt the same hand, in terms of opportunities to speak and be addresses, in terms of what each can hope to say as speaker and hearer as addressee. Conversation, in other words, is a site for the differentiation of persons, perhaps, though not necessarily, along lines established by attributes, personalities, or positions in an encompassing institutional structure."

Thus, here, the non-human agent is not only a catalyst for turn-taking, but is additional a foil for a challenge to traditional classroom hierarchies which tend to favor males over females.

What is counter-intuitively interesting about the second iteration is that the quality of the interaction–the richness of the emergent community–seems inversely related to the expectative fit of the different agents; the total number of instances of talk and movement in the first iteration are 105, compared to the second at 231. If we look at the goal of the system as essentially autopoietic (as opposed to systems that are allopoietic, created from the outside), then the number and quality of the interactions in the second example are more richly differentiated and elaborated. This is the quality of the parasite–that hermetic agent generating difference by creating noise in the system–miscommunications, conversational lapses, misunderstanding, crossed signals.

THE QUASI-OBJECT

In the above experiments, the non-human agent is on one level, subordinate to the human agents. Without their input (and in the absence of another obstacle), the non-human agent goes nowhere. On the other hand, if we look at the these interactions as emergent socialities, the non-human agent has a pivotal role–that of amanuensis for all subsequent social interaction. Without the peregrinations of what Michel Serres has called the "quasi-object", there is no emergent social interaction to begin with, like the ontological important of a ball for a game of rugby. As he summarizes in a recent interview with Bruno Latour (Serres and Latour 1995:108),

> "The ball is played, and the teams place themselves in relation to it, not vice versa. As a quasi-object the ball is the true subject of the game. It is like a track of the fluctuating collectivist around it. The same analysis is valid for the individual: the clumsy person plays with the ball and makes it gravitate around himself; the mean player imagines himself to be a subject by imagining the ball to be an object–the sign of a bad philosopher. On the contrary, the skilled player knows that the ball plays with him or plays off him, in such a way that he gravitates around it and fluidly follows the positions it takes, but especially the relations that it spawns."

That is, the quasi-object is simultaneously quasi-subject (whether human or non-human), taking on aspects of object and subject and in the process weaving a network of relations between agents. In this, the non-human agent would seem to be the sine qua non quasi-object, but humans, too, must accede to the level of quasi-object in order to function in a world of intelligent agents. As Brown (2002:21-22) writes in his summary of Serres's work:

> "Sociality is neither an automatic adding of individuals, nor an abstract contractual arrangement. It is a collectivist assembled and held together by the circulation of an object."

Conclusion

It is now axiomatic that the cognitive world varies considerably from "sense-think-act" cycle of early AI and robotics (Clark 2001:88). Now, theories of enaction, of interactivism, of emergence, suggest a dynamic, multi-directionality of perception reducible to neither the material nor the ideational world and additionally organized socially as multi-agent systems. What is less studied is the messiness of those multi-agent systems themselves, the way they involve complex "translations " (Latour) between human and non-human agents, or "transcodings" between different representational and discursive modalities. After all, the "machinic" world has the potential to discombobulate: to re-shuffle relationships and practices linking humans to the non-human world. As a corollary of this, we can also say that human participations in the machinic re-forge the machine (Deleuze and Guattari 1980:398):

> "It is through the intermediary of assemblages that the phylum selects, qualifies, and even invents the technical elements. Thus one cannot speak of weapons or tools before defining the constituent assemblages they presuppose and enter into."

In our experiment, the assemblage made up of non-human robot and PIs gives way to a new assemblage—a new network—made up of volunteers, PIs and robot. In the process, the robot's "function" shifts. It may have begun with obstacle avoidance, but, by the second iteration, becomes a gesture-machine, a conversation-machine, a turn-taking machine.

It is not too much to say that we can't say in advance of the network's formation what its components may or may not do; this is the obvious legacy of almost three decades of research in distributed cognition, autopoiesis and multi-agent systems. But HRI and HCI still, by and large, construe the human and the computer as ontologically prior to their combination which, as we have argued, is both philosophically problematic and empirically unjustified.

This also has profound implications for the design of human-computer interfaces in the classroom or the company. Is the most "user-friendly" design necessarily the best? Is there any place for resistance in the non-human agent? What do we want the non-human agent for? If it's a phone-tree, than we would want it to confirm existing expectations of human-non-human interaction but if we are in the classroom, than–counter intuitively-- it may be desirable to present a classroom of human agents with anomalous non-human agents.

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